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THE VENTILATION AND WARMING OF SCHOOL-HOUSES.

BY LEWIS W. LEEDS.

TO explain clearly and comprehensively the difference in effect between warming a room by introducing currents of heated air, and warming it by direct radiation from hotter bodies exposed in the room, I find to be a matter of much difficulty. It is, however, one of great importance in forming a correct judgment upon the best means of warming and ventilating a school-house. No more difficult problem is presented to the engineer of ventilation than the correct and entirely satisfactory heating and ventilation of a crowded school-room.

In the first place, the active and rapidly developing brains of the occupants are peculiarly sensitive to the benumbing influence of close and poisoned air; and secondly, as the pupils are confined peremptorily to fixed seats, they have not the liberty to change from one part of the room to another to avoid an unpleasant draught, or to get into a cool, refreshing breeze as a relief from the poisoned air of a foul and stagnant school-room.

It becomes an absolute necessity, therefore, that all portions of the room should be evenly warmed; while at the same time great care must be taken to avoid currents of air either hot or cold.

These requirements point directly to the necessity, for as great a distribution as possible, first, of the heat; second, of the inlets of fresh air; and third, of the outlets of the foul air.

The physiological requirements are: first, that we should always keep the feet warmer than the head; second, that we should keep the back warmer than the face. With the student, the brain is the most active portion of the body, and consequently attracts the greatest flow of blood; while the feet, which are at the greatest distance from the heart and lungs, are more liable to become chilled. In moving about we necessarily face the current; therefore, for greater protection the principal nerves and more sensitive portions of the body are placed along the back. It is very debilitating to sit with the back to a cold wall, and more especially to a cold window. But if the back and feet are kept thoroughly warm, one can safely have cold air blowing in his face for breathing.

And again, it appears to be necessary that there should be a considerable difference between the temperature of our bodies and the temperature of the air we breathe. We require that difference to be at least 28°. As soon as the air reaches the temperature of 70° we want it kept constantly in motion. Any temperature above that is more or less uncomfortable. Of course we are able to endure a much higher temperature for a short time, but it is debilitating.

On the other hand, the colder the air is, or, in other words, the greater the difference between the temperature of the air we breathe and that of our bodies, the more rapidly the blood circulates and the greater is the physical action of the system. There is twice the quantity of carbonic acid given off when we are breathing air from 10° to 20° than when the air is from 80° to 90°. Every one knows how much more he can do on a clear, bright day in winter, than on a hot, sultry day of summer. Our great aim should be to produce, so far as need be, these most favorable conditions in our school-houses.

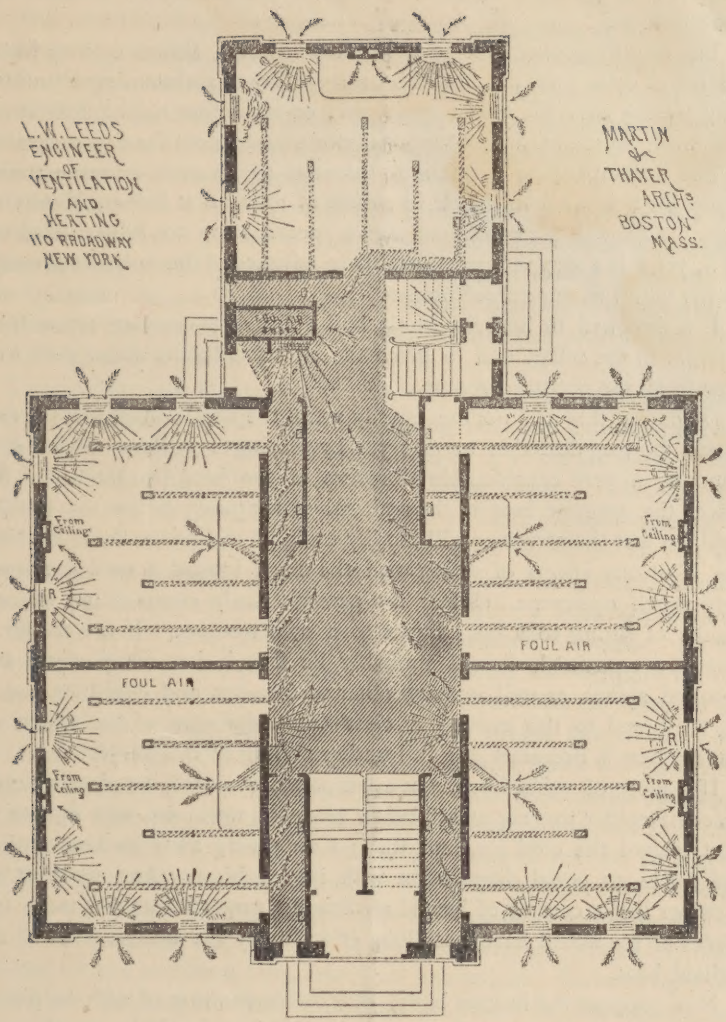
To recapitulate : The room should be warmed and ventilated in all parts alike ; there should be no perceptible current in any part ; the feet of the occupants should be kept warmer than their heads ; their backs should be warmer than their faces ; and, finally, their bodies should be kept warm, while they have cool invigorating air for breathing.

Now to produce these results, I can scarcely see how we can avoid coming directly to the conclusion that we should warm the floor and exterior walls to a temperature equal to that of our bodies, 98°, so as to prevent the absorption of the radiant heat from our bodies by the walls. We could then afford to have cool air for breathing, say air at a temperature of 50°. The sun's rays heat much hotter than this even in winter. I have placed a thermometer in a box, protected from draughts and covered with a glass, in a snow-bank, in the direct rays of the sun. It soon rose to 182°, and I believe that carefully conducted experiments have shown that the direct radiation from the sun is sufficient to boil water, even in winter.

It is the important fact that the rays of heat from a hot body pass through pure air without heating it, which makes direct radiation so essentially different from heating by currents of warmed air.

In a room heated by warm air, all the air must be hotter than is required for breathing. It is very commonly heated upwards of 100°; the solid objects in the room are much colder, and consequently are constantly absorbing the vital heat from the bodies of the occupants, while they are breathing this warm, debilitating air. It is this condition of things that gives that uncomfortable feeling so universally complained of in all rooms warmed by hot air.

On the other hand, it is the powerful direct radiation that comes from



PLAN OF SALEM SCHOOL-HOUSE, FIRST FLOOR.

the glowing flames of an open fire, often at a temperature of near 3000°, that makes it so nearly correspond with the radiation from the sun, and enables it to produce an artificial warmth unequalled for comfort and healthfulness.

The requirements of the school-room, however, almost entirely forbid the use of open fires, owing to the impossibility of maintaining a uniform temperature over the whole room, and certain other minor difficulties. We must, therefore, accept some inferior arrangement for that purpose.

The accompanying diagram is intended to illustrate an arrangement made for a new school-house in course of erection at Salem, Massachusetts. Although the conditions above specified are not fully carried out in it, yet it is a step very considerably in advance of the ordinary arrangements found in our school-houses.

It is designed to heat the whole building by low-pressure steam from a boiler in the cellar, and to place the steam radiators under each window in all the occupied rooms.

Of course this will not necessarily warm the whole interior wall, as it would be very desirable to do; yet by placing a radiator under each window, a very considerable diffusion of the heat is obtained. Besides, the greatest heat is thus placed immediately below the greatest cold, so that the extremes will modify each other, and at the same time the injurious effects of sitting with the back toward a cold window is very much overcome. I fear few persons really comprehend the sad results of sitting with their backs to a cold window. If the matter is carefully examined, it will probably be found that many weak and crooked spines, as well as many other weaknesses and debilities, are to be attributed to this cause. A clear comprehension of the effects of radiant heat is necessary to a full understanding of this subject.

If a piece of warm ice, say at a temperature of 31°, be placed near a piece of colder ice, say at 15° below zero, the warm ice will radiate its heat toward the cold ice, and will go on giving away its heat until it has made an equal distribution with its neighbor. And we must remember that a current of heated air flowing upward between these two pieces of ice would have but little effect upon the transmission of the radiant heat.

Now suppose the human body, with its temperature of 98°, be placed near a cold window or wall, the radiation of heat would be much more rapid than it would be from the warm ice, and not being returned or compensated for, the heat, the vitality, the very essence of life would be rapidly extracted from the body. And we must not commit the fatal error of supposing that a thermometer will correctly indicate the true condition of things. While a person may be surrounded by and inhaling a most debilitating atmosphere of 75° or 80°, this does not prevent the

loss of heat by radiation ; it rather aggravates the evil by reducing the circulation of the blood, thus lessening the amount of natural heat produced.

The distribution of the inlets of fresh air and outlets of foul air is of not less importance. Fresh air should be so thoroughly diffused that while there could be no possibility of stagnation, there would be no considerable currents perceptible anywhere. The diffusion of fresh air is quite well provided for by the introduction of air directly under every window and over the radiators.

The manner in which I arrange this is to place the marble slab covering the radiator from two to four inches above the bottom of the sash. Then by simply raising the window the fresh air flows in at the top of the radiator. Its specific gravity being greater than that of the air within, it falls over the face of the radiator, insuring about as perfect a diffusion of pure air as it is possible to have.

The proper place for the exit of the foul air has been much discussed. A few years ago no one thought of anything but taking it from the top of the room ; then as soon as it was attempted to warm the room by circulating warmed air, the ventilators had to be closed. Now, the tendency is to run to the other extreme, and to have the only opening at the bottom of the room. This also is wrong, as the excess of the foul air is at the top probably three-fourths of the year. As great a distribution of outlets as possible is therefore important. I think the agitation of the air is the great means designed to maintain its purity. In the Salem school have been provided, as may be seen, five registers for the escape of foul air from each class-room. These will be equal to an opening of one square foot each, or about one square foot for every ten children. Of course this arrangement is not perfect, but it will answer its purpose tolerably well. The space between the joists, under the class-rooms, is used for foul-air ducts. The ceiling of the hall is furred down from fourteen to twelve feet, leaving a space of two feet for a general foul-air duct, to convey the air to the main upright shaft. Great care is required in the proper proportioning of these air-ducts and in separating them one from another so that they shall all draw evenly, and the foul air not be blown from one room to another. Failures have occurred in attempting to ventilate through the floors in this manner, for want of proper care in this respect. Some power is always required to move the air, as it will no more move itself than water or coal. The variation in the external temperature is the great natural moving-cause. Our buildings obstruct this to a great extent. Artificial heat in the building causes a circulation, but there should be in every good school-house, besides these varying natural forces, a constant positive power always in operation. I think we have nothing at present more simple and

efficient than the application of heat to a well-constructed shaft. The smoke-pipe from the boiler or furnace fires generally gives sufficient heat in the shaft during very cold weather, and a good stove or furnace is the best for procuring the required additional temperature during the warmer weather. Ambitious young engineers of ventilation are very apt to adopt the Fan, as that gives a fine opportunity for the display of their engineering abilities. It generally proves, however, very unsatisfactory in result.

The perfection of arrangements for providing artificial warmth has, for many centuries, been a good criterion of a nation's advancement in civilization; but I think a new era is dawning, in which a nation's ability to keep warm, and at the same time supplied with pure air, will be a much more accurate test of its elevation above barbarism. And I hope that our American Schools will be as prompt in taking the advance in this, as they have been in the many other improvements that have given them their enviable reputation throughout the world.